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# Groundwater Quality Assessment: A Case Study of Manpur, India

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## *Abstract*

*The main objective of this study is to evaluate the groundwater quality in the Manpur block of Gaya District, Bihar, India for drinking purpose. Collection, process and analysis of different physicochemical parameters such as pH, calcium, magnesium, conductivity, total hardness, total alkalinity, total dissolved solids, nitrate, chloride, fluoride, sulphate, iron and arsenic have been conducted for about one hundred ten groundwater samples. The study revealed that in all the groundwater samples pH, chloride, total arsenic, magnesium, nitrate and sulphate were found under the BIS acceptable limit. The pH was negatively and arsenic was not correlated significantly with most of the analysed parameters. The positive correlations are seen among electrical conductivity, alkalinity, total dissolved solids and total hardness and also with calcium, magnesium, sulphate, nitrate and chloride. Whereas iron and fluoride were not significantly correlated to each. The total dissolved solids, total alkalinity, total hardness, iron, fluoride and calcium exceeded the BIS acceptable limit which severely affects the groundwater in the study area.*

**Keywords:** *Correlation coefficients; Drinkingwater; Groundwater; Physicochemical.*

## 1. INTRODUCTION

The groundwater is the most significant source of drinking purpose throughout the world as well as in India. The majority of the people depend upon groundwater for drinking purpose as it is the solitary source in India. It occurs almost everywhere below the earth surface in thousands of local aquifer, and not in a single widespread aquifer (Vasanthavigar *et al.* 2010). Groundwater is not a rich water source present in aquifers, where it is accumulated and moves steadily through the geologic formations of soil, sand and rock. About 90% of rural households and 30% of urban depend entirely on untreated groundwater or surface water (Palanisamy *et al.* 2007).

Approximately 80% of diseases are waterborne in human beings as per World Health Organization (WHO). Due to waterborne diseases, the mortality and morbidity rates are high in India. The deterioration of the groundwater quality is the result of human activities and natural processes (Andrade *et al.* 2008; Kouras *et al.* 2007; Gu *et al.* 2017). The placement of a large number of unwanted contaminants into ground and surface water have been caused by Anthropogenic activities such as industrialization, excessive use of inorganic fertilizers, pesticides, herbicides, domestic and industrial wastewater and extreme use of groundwater (Singh *et al.* 2004; Girija *et al.* 2007; Devic *et al.* 2014; Selvakumar *et al.* 2017). Thus, both surface and groundwater pollution are driven by anthropogenic activities (Niemi *et al.* 1990; Ayotte *et al.* 2011; Singh et. al., 2018).

Groundwater contamination due to industrial pollutants are promising with both national and international issues. Development and management of groundwater resources play a very important role in agriculture, poverty, human health, environment and sustainable development. Deterioration of groundwater quality requires urgent consideration. Therefore, previous studies reported the groundwater quality in West Delhi (Adhikary *et al.* 2009), Garwa, Jharkhand (Avishek *et al.* 2010), Nainital, Uttarakhand (Jain *et al.* 2010), Jaipur, Rajasthan (Tank & Chandel, 2010), Thirumanimuttar sub-basin, Tamilnadu (Vasanthavigar *et al.* 2010), Belgaum, Karnataka (Ravikumar *et al.* 2010), Krishna Delta, Andhra Pradesh (Mondal *et al.* 2010), Ghaziabad, Uttar Pradesh (Singh *et al.* 2012), Rural Bihar (Srikanth, 2013), Samastipur, Bihar (Kumar *et al.* 2016).

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Groundwater quality studies for Manpur block in Gaya district, Bihar (India) are inadequate. A groundwater pollution dtabase in this area is required. The objective of the study was to assess the groundwater quality for drinking purpose in Manpur block situated about 8 Km towards east from district headquarters Gaya and 104 Km from state capital Patna towards the north.

## 2. MATERIALS & METHODS

Manpur block is in Gaya district of Bihar state, India and belonging to Magadh division (Fig. 1) with headquarters as the Manpur town. It is bounded by Gaya block towards west, Atri block towards the east, Tankuppa block towards the south, and Bodhgaya block towards the west and situated on the banks of the Phalgu river at an elevation of 113 m. The town is known for its handlooms and railroad tie factory. It is a country town where the people from the remote villages do their shopping. The main occupations of the people are business and handloom weaving and it is referred to as mini- Kanpur by people.

110 groundwater samples were collected from 110 different hand-pumps after flushing water for 10–15 minutes to eliminate the stagnant water that was extensively used for drinking and other domestic purposes of the study area which includes Manpur block of Gaya District, Bihar. Before groundwater sampling, the containers were washed, rinsed and dried. The groundwater samples were collected and analyzed according to standard methods (APHA, 2000) and procedure, with suggested precautions being taken to avoid contamination. The various parameters such as pH, total dissolved solids and electrical conductivity were determined by pH meter, TDS meter and conductivity meter respectively during onsite sampling. The other parameters like total hardness and alkalinity were analysed by titrating the sample with EDTA and sulphuric acid respectively. The titrimetric analysis was also used to analyze chloride, calcium and magnesium concentrations. Total alkalinity was estimated by acid-base titration. Total arsenic and iron in the acid digested samples were also measured. In addition to this, the sulphate, nitrate as well as fluoride were determined by using a spectrophotometer.

To evaluate the potential relationship between various physicochemical parameters, statistical analysis like maximum, minimum, mean, median, standard deviation and correlation coefficients were carried out by using “IBM Statistical Package for the Social Sciences (SPSS) – 21”.

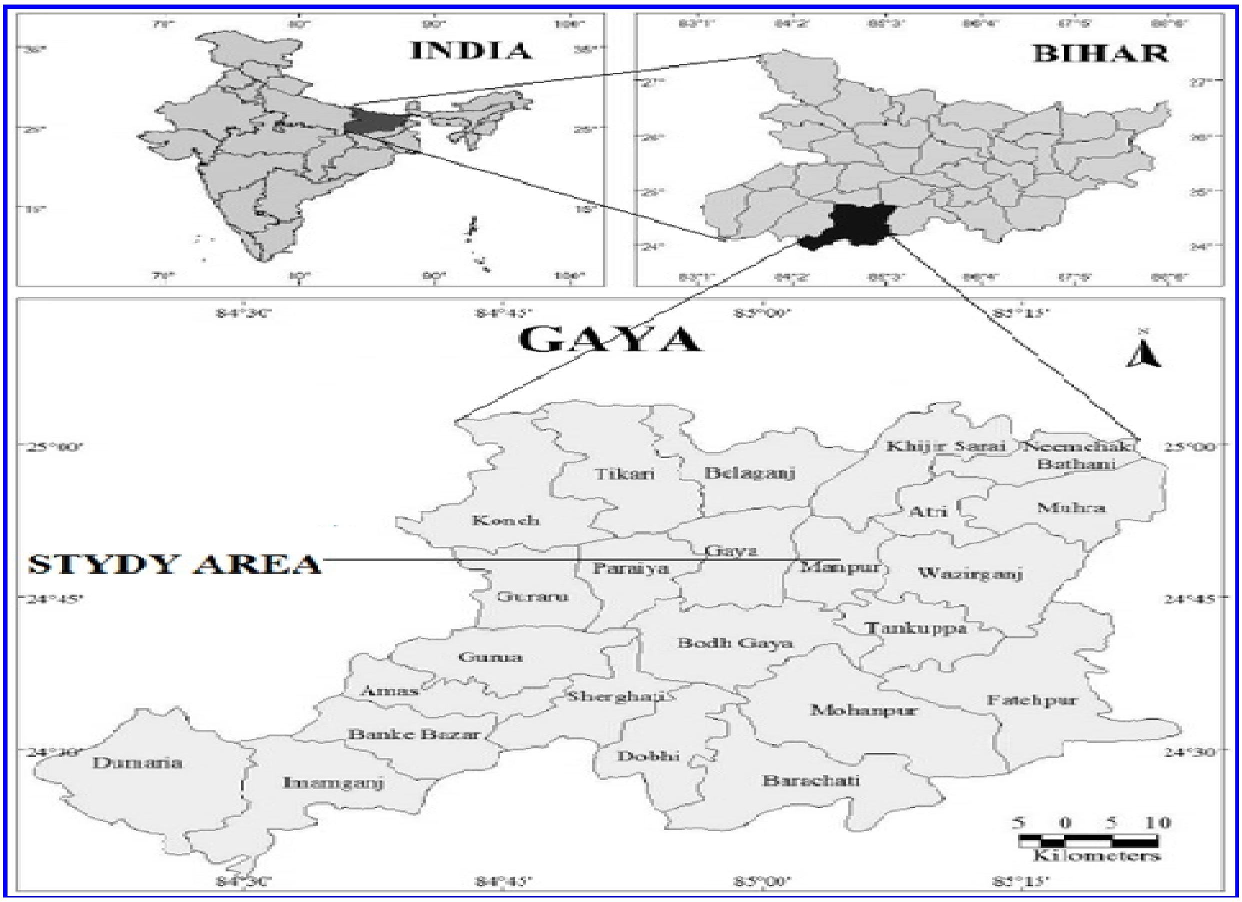


**Fig. 1: Location map of the study area**

## 3. RESULTS & DISCUSSION

In groundwater quality assessment the estimation of its physical and chemical characteristic is essential as it determines the suitability of this water for drinking purposes. As such the appropriateness of groundwater for potable uses with regard to its physicochemical characteristic has to be deciphered and defined on the basis of some essential characteristics of the water. Drinking water quality standards recommended by the Bureau of Indian Standards (BIS, 2012), has been used for finding the suitability of groundwater. The groundwater quality of the Manpur block is evaluated by comparing the range of values of different physicochemical parameters of drinking water with Bureau of Indian Standards (BIS, 2012). The summarized physicochemical parameters and its comparison with Bureau of Indian Standards (BIS, 2012) are presented in Table 1.

The groundwater properties in the study area, regarding central parameters, for example, pH, electrical conductivity, total dissolved solids and hardness are discussed below. The pH varied from 6.5 to 7.5 with a mean value of 6.9 (Fig. 2). Hence the groundwater in the study area was mildly acidic to slightly alkaline but for human use, all the samples were considered to be suitable, as they were found within the recommended limits for human consumption which is 6.5-8.5, as per BIS (2012). The electrical conductivity within 400 µmhos/cm at 250C is considered fit for human use, whereas more than 1,500 µmhos/cm at 250C may cause corrosion of iron structures (Umar & Alam, 2012). The electrical conductivity (EC) values were found to be within the range of 328 µmhos/cm to 3172 µmhos/cm with a mean value of 1057 µmhos/cm (Fig. 3).

**Table 1. The summaried physicochemical parameters and its comparison with Bureau of Indian Standards (BIS, 2012)**

| Parameter | Minimum | Maximum | Mean | Median | Standard Deviation | Indian Standard (BIS, 2012) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Requirement (Acceptable Limit) | Permissible Limit in the Absence of Alter Source |
| pH value | 6.5 | 7.5 | 6.9 | 6.9 | 0.21 | 6.5-8.5 | No Relaxation |
| Electrical conductivity (µS/cm) | 328 | 3172 | 1057 | 921 | 554.27 | -- | -- |
| Total dissolved solids (mg/l) | 188 | 2007 | 641.4 | 570 | 346.26 | 500 | 1500 |
| Calcium (as Ca) (mg/l) | 33 | 248 | 100.5 | 92 | 42.85 | 75 | 200 |
| Chloride (as Cl) (mg/l) | 5 | 247 | 71.66 | 46 | 55.78 | 250 | 1000 |
| Fluoride (as F) (mg/l) | 0.30 | 4.88 | 1.72 | 1.07 | 1.35 | 1.0 | 1.5 |
| Iron (as Fe) (mg/l) | 0.06 | 2.24 | 0.61 | 0.54 | 0.43 | 0.3 | No Relaxation |
| Total arsenic (as As) (µg/l) | 3 | 9 | 5 | 6 | 2 | 10 | 50 |
| Magnesium (as Mg) (mg/l) | 3 | 71 | 24.36 | 22 | 13.93 | 30 | 100 |
| Nitrate (as $NO_3$) (mg/l) | 0.21 | 30.77 | 7.44 | 6.70 | 5.21 | 45 | No relaxation |
| Sulphate (as $SO_4$) (mg/l) | 4 | 161 | 27.95 | 24 | 22.92 | 200 | 400 |
| Total alkalinity (as $CaCO_3$) (mg/l) | 112 | 821 | 377.5 | 351.5 | 156.45 | 200 | 600 |
| Total hardness (as $CaCO_3$) (mg/l) | 96 | 794 | 352.1 | 333 | 145.29 | 200 | 600 |

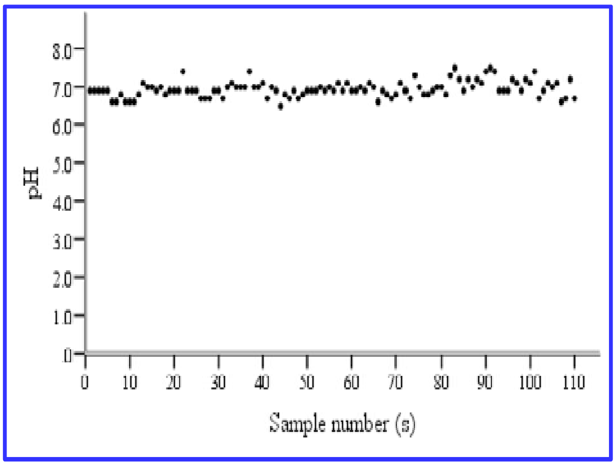


**Fig. 2: The Concentration of pH in groundwater samples**

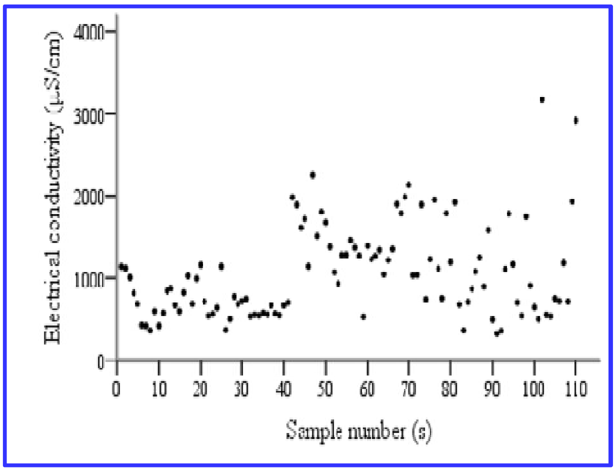


**Fig. 3: The concentration of electrical conductivity in groundwater samples**

In groundwater sources, total dissolved solids consist of a lot of minerals. In a trace amount, various dissolved gases and organic matter are also present (Jain *et al.* 2010). The Total Dissolved Solids (TDS) concentration varied from 188 mg/l to 2007 mg/l with a mean value of 641.4 mg/l and standard deviation of 346.26 mg/l in groundwater samples. Only two groundwater samples exceeded the permissible limit of 1500 mg/l but about 55% samples exceeded the acceptable limit of 500 mg/l (BIS, 2012) (Fig. 4). TDS values of less than 500 mg/l are considered to be good and more than 1,000 mg/l becomes significantly unpalatable for drinking purpose (Umar & Alam, 2012). Therefore, in the study area groundwater was not truly ideal. High concentration of TDS may incite a troublesome physiological response in the transient consumer and gastrointestinal aggravation if utilized for drinking purposes (Shankar *et al.* 2008).

The alkalinity of the drinking water has little public health significance. Dissolution of $CO_2$ in groundwater results in alkalinity in natural groundwater. Carbonates and bicarbonates thus formed are dissociated to yield hydroxyl ions. The total alkalinity was found in the range of 112 mg/l – 821 mg/l in groundwater samples with a mean value of 377.5 mg/l and standard deviation of 156.45 mg/l. Approximately 92% samples exceeded the acceptable limit of 200 mg/l but only 13 % samples exceeded the BIS permissible limit of 600 mg/l (BIS, 2012) (Fig. 5).

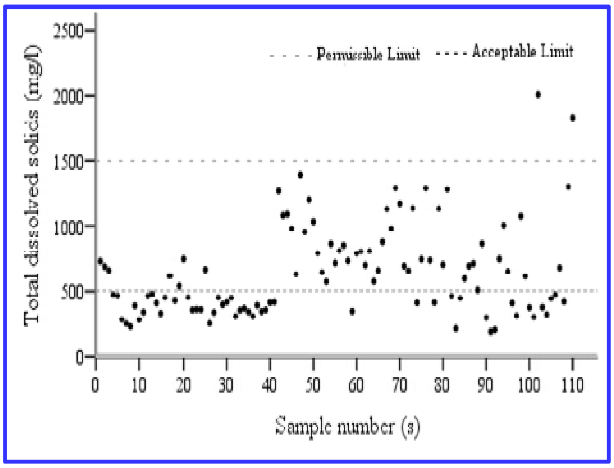


**Fig. 4: The concentration of total dissolved solids in groundwater samples**

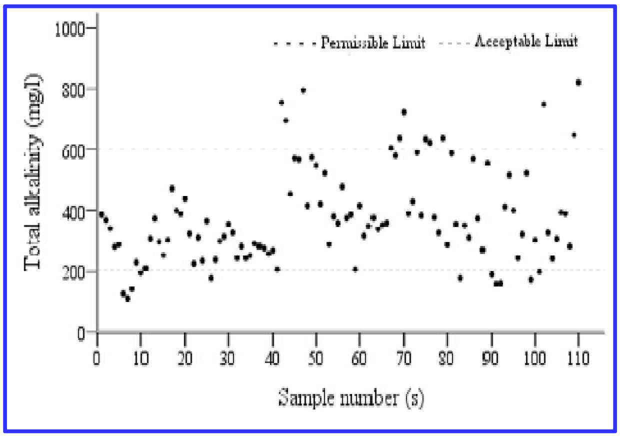


**Fig. 5: The concentration of total alkalinity in groundwater samples**

The total hardness values ranged from 96 mg/l – 794 mg/l in the study area with mean and median values of 352.1 mg/l and 333 mg/l respectively and standard deviation of 145.29 mg/l. Only 9 % of the samples were under the BIS acceptable limit of 200 mg/l and 6% samples exceeded the BIS permissible limit (BIS, 2012) (Fig. 6). Therefore, the groundwater can be categorized under hard to the very hard category.

The calcium ion ($Ca^{++}$) concentrations in the study area ranged from 33 mg/l to 248 mg/l with a standard deviation of 42.85 mg/l. About 71% samples exceeded the acceptable limit of 75 mg/l but only two groundwater samples exceeded the BIS permissible limit of 200 mg/l (BIS, 2012) (Fig. 7). The magnesium (Mg) concentration varied from 3 mg/l to 71 mg/l with mean and median values of 24.36 mg/l and 22 mg/l respectively. No samples exceeded the magnesium BIS permissible limit of 100 mg/l (Fig. 8). According to the

relative abundance in rocks, generally, the calcium ion concentrations in groundwater exceeded the magnesium ion concentrations (Jain *et al*. 2010).

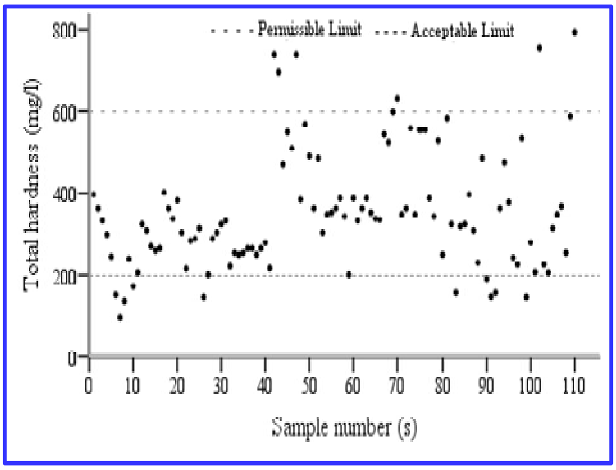


**Fig. 6: The concentration of total hardness in groundwater samples**

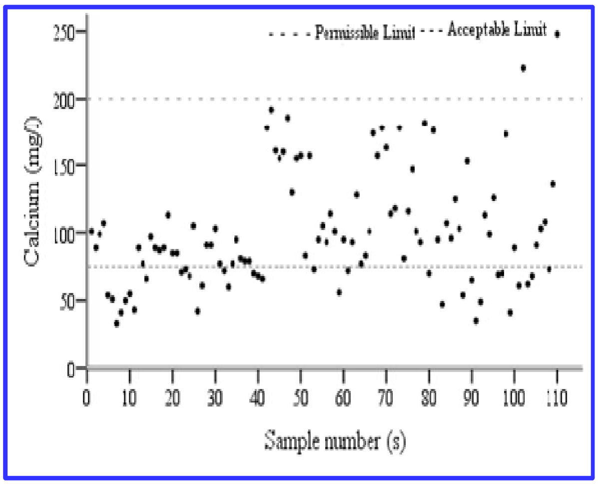


**Fig. 7: The concentration of calcium in groundwater samples**

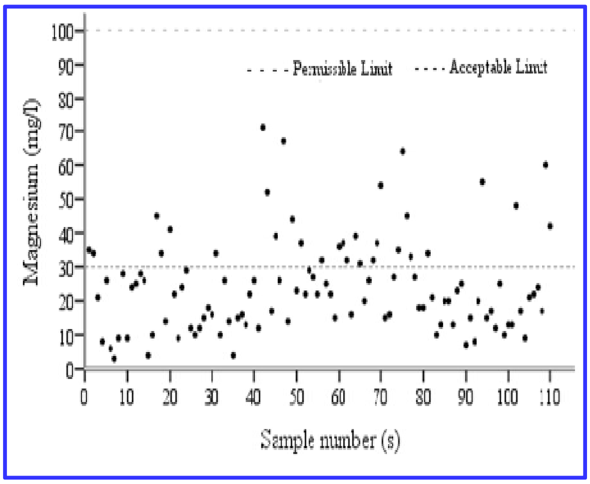


**Fig. 8: The concentration of magnesium in groundwater samples**

The chloride ($Cl^-$) concentration in groundwater samples shows a wide variation from a minimum of 5 mg/l to as high as 247 mg/l with a standard deviation of 55.78 mg/l. All the groundwater samples in the study area are found within the BIS acceptable limit of chloride i.e. 250 mg/l (Fig. 9). High chloride concentrations in drinking water have no adverse health impacts on a human being (Jain *et al.* 2010).

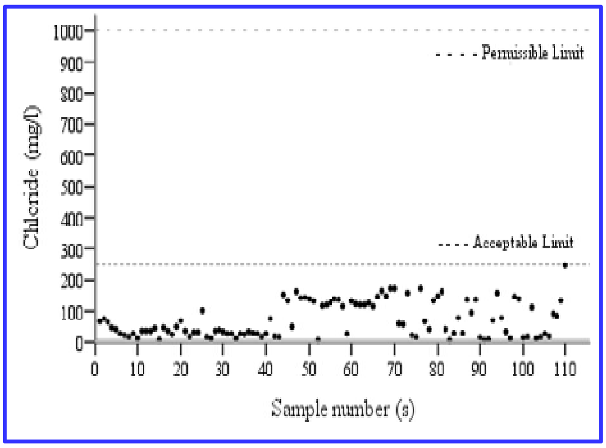


**Fig. 9: The concentration of chloride in groundwater samples**

Major change takes place with time in sulphate ion concentration by groundwater recharge due to rainfall infiltration (Jain *et al.* 2010). In the groundwater samples, the sulphate concentration varied from 4 mg/l to 161 mg/l with a mean value of 27.95 mg/l. All the groundwater samples are found below the BIS acceptable limit of 200 mg/l (BIS 2012) in the study area (Fig. 10). Sulphate alone has no adverse impact on health but it may cause gastrointestinal irritations when it is more than 400 mg/l with sodium or magnesium (Shanker *et al.* 2008).

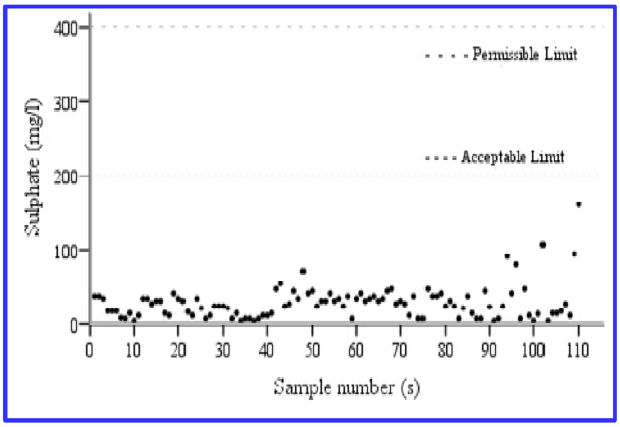


**Fig. 10: The concentration of sulphate in groundwater samples**

In many parts of India, high nitrate concentrations are reported in groundwater due to excessive use of nitrogen fertilizers in agriculture. More than 45 mg/l nitrate ($NO_3$) in drinking water causes methemoglobinemia or blue baby syndrome (Jain *et al.* 2010) and Gastric Carcinoma (Tank & Chandel, 2010). The concentration of nitrate ranged from 0.21 mg/l to 30.77 mg/l with a mean value of 7.44 mg/l. All

groundwater samples were found within the BIS (2012) acceptable limit of 45 mg/l (Fig. 11).

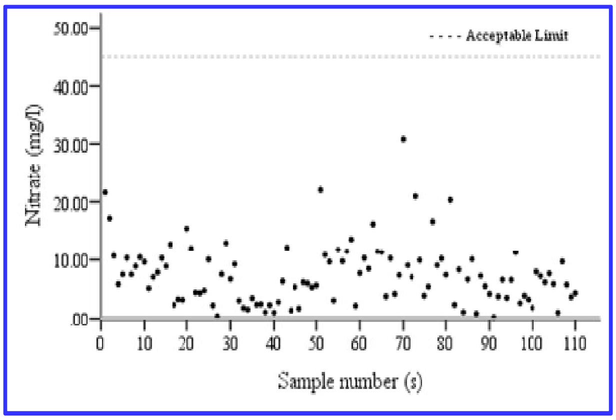


**Fig. 11: The concentration of nitrate in groundwater samples**

Worldwide the range of fluoride concentration in groundwater is 0.01 to 48 mg/l, which causes fluorosis and has an adverse impact on teeth, and bones. Fluoride contaminated drinking water is imposing a serious threat to human health as one of the major problems. Fluoride generally occurs as a natural constituent in the groundwater. With a mean value of 1.72 mg/l the fluoride (F-) concentration varied from 0.30 mg/l to 4.88 mg/l in the study area. About 54% samples were found within the acceptable limit of 1 mg/l as per the BIS (2012), whereas about 43% samples exceeded the permissible limit of 1.5 mg/l (Fig. 12).

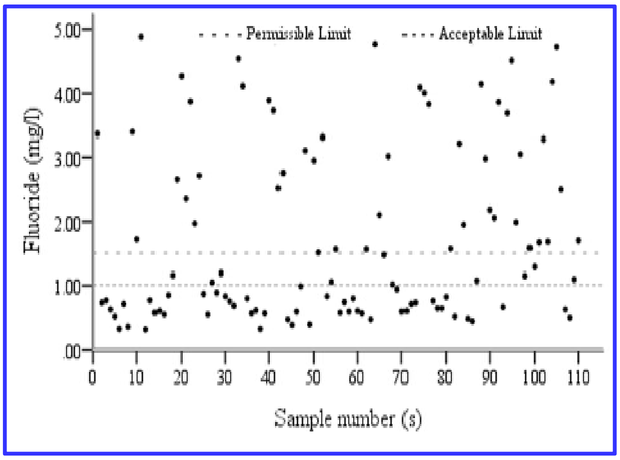


**Fig. 12. The concentration of fluoride in groundwater samples**

High concentrations of iron in groundwater result in turbidity, reconsider inky flavor, bitter and astringent taste. Groundwater, while pumping out, remains clear having soluble iron but when it exposes to air causes turbidity and rusty color due to precipitation of iron causes (Jain *et al.* 2010). In aquifers, high iron concentration occurs, due to the interaction of oxidized Fe-bearing minerals and organic matter and subsequent dissolution of Fe2CO3 at lower pH. Another possibility is that reduced conditions due to the dissolved oxygen removal by organic matter results in increasing the solubility of Fe-bearing minerals (Mondal *et al.* 2010). In groundwater samples, the iron (Fe) concentration varied from 0.06 mg/l to 2.24 mg/l with a standard deviation of 0.43 mg/l. Only 28 % samples were found within the acceptable limit of 0.3 mg/l as per the BIS (2012) (Fig.13).

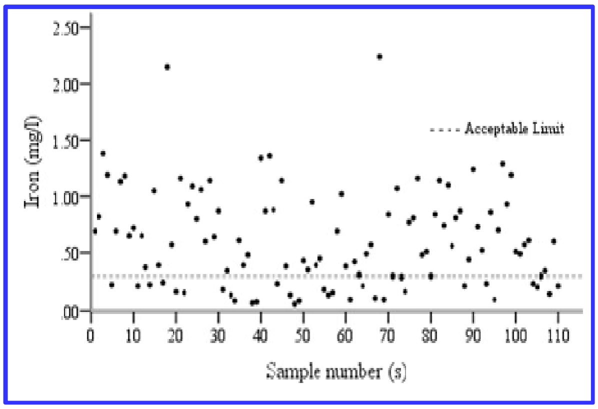


**Fig. 13: The concentration of iron in groundwater samples**

Arsenic (As) contamination of groundwater is one of the most significant environmental evils. Melting operation, fossil fuel combustion, fertilizers, agrochemical and disposal of municipal and industrial wastes are the geologic and anthropogenic actions due to which it is prevalent (Requejo & Tena, 2006). Cancers, lung diseases, heart diseases, and hyperkeratosis occurs in humans due to drinking water arsenic contamination (Mandal & Suzuki, 2002). The arsenic concentration in groundwater samples of study area ranged from 3 µg/l to 9 µg/l with a mean value of 5 µg/l and all groundwater samples are found very less to the BIS (2012) acceptable limit of 10 µg/l (Fig. 14).

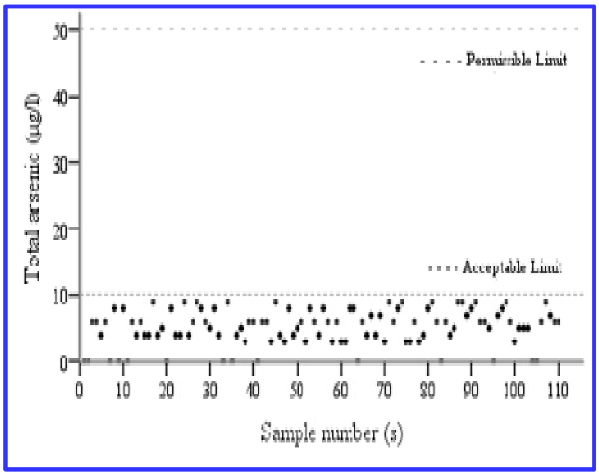


**Fig. 14: The concentration of total arsenic in groundwater samples**

A statistical measure of interrelationship and coherence pattern of two or more random variables is the Pearson's correlation coefficient which measures the degree of linear association and the closeness between independent and dependent variables. Correlation matrix presents the correlation coefficient value of the

analyzed parameters in groundwater quality data (Table 2). Except for iron, magnesium and arsenic, most of the physicochemical parameters were negatively correlated with the pH. Arsenic was not significantly correlated with any of the analysed physicochemical parameters. The significantly positive correlations are seen among alkalinity, electrical conductivity, total hardness and total dissolved solids and also with calcium, magnesium, sulphate, nitrate and chloride. The dependency of conductivity on total dissolved solids results in the high correlation between electrical conductivity and total dissolved solids (Singh *et al.* 2012).

**Table 2. Correlation matrixes for different water quality parameters**

| | pH | EC | TDS | TH | Ca | Mg | F | Fe | As | Cl | $SO_4$ | $NO_3$ | AKL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **pH** | 1 | | | | | | | | | | | | |
| **EC** | -0.31 | 1 | | | | | | | | | | | |
| **TDS** | -0.31 | 0.99 | 1 | | | | | | | | | | |
| **TH** | -0.26 | 0.92 | 0.91 | 1 | | | | | | | | | |
| **Ca** | -0.28 | 0.89 | 0.88 | 0.94 | 1 | | | | | | | | |
| **Mg** | -0.14 | 0.67 | 0.66 | 0.77 | 0.51 | 1 | | | | | | | |
| **F** | 0.22 | -0.03 | -0.03 | 0.00 | -0.07 | 0.13 | 1 | | | | | | |
| **Fe** | -0.01 | -0.10 | -0.11 | -0.04 | -0.03 | -0.04 | -0.11 | 1 | | | | | |
| **As** | 0.06 | 0.08 | 0.08 | 0.05 | 0.08 | -0.03 | -0.29 | 0.08 | 1 | | | | |
| **Cl** | -0.31 | 0.81 | 0.80 | 0.61 | 0.60 | 0.41 | -0.13 | -0.21 | 0.12 | 1 | | | |
| **$SO_4$** | -0.21 | 0.74 | 0.73 | -0.07 | 0.64 | 0.48 | 0.04 | -0.07 | 0.04 | 0.57 | 1 | | |
| **$NO_3$** | -0.19 | 0.27 | 0.24 | 0.23 | 0.18 | 0.24 | -0.09 | 0.09 | -0.08 | 0.27 | 0.16 | 1 | |
| **ALK** | -0.22 | 0.91 | 0.89 | 0.98 | 0.92 | 0.75 | -0.01 | -0.21 | 0.05 | 0.60 | 0.61 | 0.22 | 1 |

Iron and Fluoride were not significantly correlated and also not significantly correlated with electrical conductivity, total dissolved solids, total hardness, magnesium, calcium, sulphate, nitrate, arsenic and alkalinity as well as calcium and magnesium was significantly correlated and also significantly correlated with chloride, sulphate. Nitrate was positively and significantly correlated with chloride and magnesium but not significantly correlated with sulphate and calcium. Chloride was positively correlated with sulphate and no significant relationships were found with fluoride.

## 4. CONCLUSION

The study revealed that in all the groundwater samples pH, chloride, total arsenic, magnesium, nitrate and sulphate were under the BIS acceptable limit. The total dissolved solids in 55%, total alkalinity in 92%, total hardness in 91%, calcium in 71%, fluoride in 46% and iron in 72% samples exceeded the BIS acceptable limit. For consumption in domestic purposes, this water should be treated first.

For thirteen variables the correlation matrices were formed. The pH was negatively and arsenic was not significantly correlated with most of the analysed physicochemical parameters. Electrical conductivity, alkalinity, total dissolved solids and total hardness are seen significantly positive correlated and furthermore with calcium, magnesium, sulphate, nitrate and chloride. Iron and Fluoride was not significantly correlated and furthermore not significantly correlated with electrical conductivity, total hardness, total dissolved solids, calcium, magnesium, sulphate, nitrate, arsenic and alkalinity.

In the study area, the groundwater was severely affected by total alkalinity, total hardness, total dissolved solids, iron, calcium, and fluoride.

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